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Dependence of pattern of neuron-type conducting polymer metwork on polymerization conditions and its simulation

Masaharu Fujii, Haruo Ihori and Kiyomitsu Arii
Department of Materials Science and Engineering,
Faculty of Engineering, Ehime University,
3 bunkyo, Matsuyama, Ehime 790-8577, Japan
Tel:+81-89-927-9892, Fax:+81-89-927-9907
E-mail:mfujii@en2.ehime-u.ac.jp

1. Introduction

Conducting polymers with fractal patterns have been polymerized electrochemically under some conditions. When the polymerization conditions change during polymerization, the pattern of conducting polymer changes. If the conditions are controlled, neuron-like conducting polymer is prepared: the shape of the center as cell body and nucleus is disk and the branch correspond to dendrite. Two neuron-type conducting polymer can be connected each other; a channel corresponds to axon. When this connected process is repeated, a network of neuron-type conducting polymer can be prepared. These patterns of network of conducting polymer depend on the polymerization conditions such as applied voltage, the concentration of monomer and electrolyte, temperature, moisture, etc[1]. The number and the width of the channels between two neuron-type conducting polymers depend on the conditions. Thus the pattern strongly depends on the experimental conditions, i.e. the environmental ones. This means that the@weight of channels of conducting polymer network depends on the environment conditions.

In general conducting polymers have many good properties. Furthermore if the channels in the network of conducting polymer changes its weights when the electrical pulses pass through them, this network works as a neuron device. This device has two special features: functions of neuron and its configuration. When the device is prepared, the environmental conditions are built in the configuration of the network. Actual neurons also grow under the effect of some conditions and its patterns also depend on the conditions.

The patterns of neuron-type conducting polymers depend on the experimental conditions. The concentration of monomer and electrolyte in the polymerization solution changes actually during preparation of conducting polymer. The pattern of the conductive polymer also changes under changing conditions. Therefore it is possible to understand the change of conditions by checking the change of the growth pattern of neuron-type conducting polymer. For making network device of neuron-type conductive polymer, it is desirable to know the growth mechanism of the pattern. This growth mechanism resembles the DLA(Diffusion-Limited Aggregation) model one. In the case of conducting polymer, monomer, electrolyte and polymerization voltages are necessary. The growth pattern of neuron-type conducting polymer can be estimated by modifying the DLA model. It is possible to discuss the growth mechanism of the actual pattern by simulating the growth pattern.

In this paper, the dependence of the pattern on polymerization condition is shown, and the growth model is simulated.

2. Simulation of neuron-type conducting polymer using Modified DLA model

The pattern depends on the polymerization conditions; especially the applied voltage and the concentration of monomer and electrolyte. Monomer moves randomwalkly and electrolyte ion moves along the electric

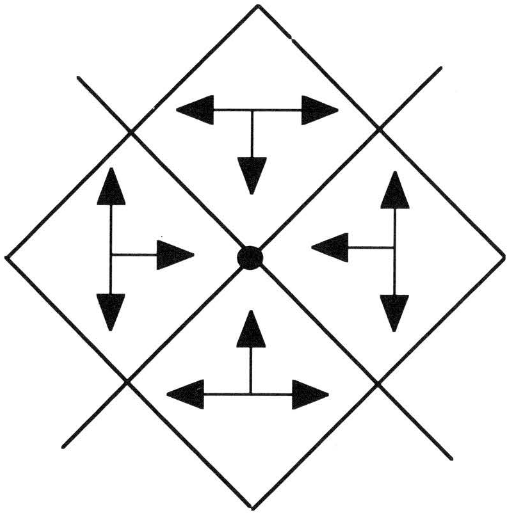

Fig.1 movement of particle
The center point is needle electrode.
The rhombus is the particle production region.

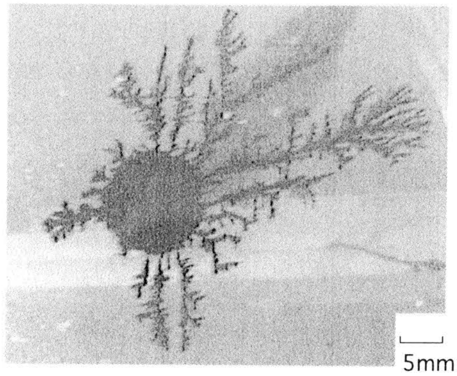

Fig.2 neuron-type conducting polymer

field. Solvent flows along the ion motion. Therefore potential distribution must be consider for simulation of the growth pattern.

In general, the polymerization process of conducting polymer is explained as follows. At first an electron in a monomer is removed at the anode surface. The resultant radical monomer encounters another radical or oligomer and then loses two alpha hydrogens. This process is repeated. At the same time the counter ion is taken inside. The tip of the conducting polymer acts as new electrode. Thus conducting polymer grows as DLA model.

The particle in this model can moves in two way: one is random walk another is to walk 3 direction except the opposite direction of electrode as shown in Fig. 1. The center point is the needle electrode. The particle production region is the rhombus. Particle walks and hit the electrode and then particle stop. The pattern grows. Next new particle appears on boundary and then walk again. When it encounters electrode or deposited particle, the pattern grows. This process is repeated.

2. Experimental

Neuron-type conducting polymer is polymerized electrochemically with a needle anode of Pt and a ring cathode of Ni whose diameter is 7cm and its high is 1cm. Polypyrrole is prepared electrochemically. Acetonitrile and *p*-toluenesulfonate is used as solvent and electrolyte respectively and the changes in the shape of the neuron-type conducting polymers are observed because the shapes depend on the polymerization conditions. When two neuron-type conducting polymers are connected, each conducting polymer consists of two parts: the center body is disk-like as a soma (or cell body) and the many branches grow from the edge of the disk. The branch corresponds to a dendrite. Each branch of two neuron-type conducting polymers approaches each other, and then the voltage is applied between two disks. Thus the branches are connected. The connected branch corresponds to an axon.

The network of neuron-type conducting polymer with eight sites is prepared using eight needle electrodes and one ring electrode. Each needle electrode puts on the cell 2cm away. In order to make the same size of the neuron-type conducting polymer, the needle electrode applied the voltage is changed in turn. When the disks of the conducting polymer grow to certain size, the monomer is added. Many small branches grow from the edge of the disk. The mode of growth changes. When the branches approach each other, the applied voltage is turned off. Then the arbitrary network can be prepared by applying the voltage between the chosen branches.

3. Results and discussion

Figure 2 shows the neuron-type conducting polymer of polypyrrole: monomer,20ml/electrolyte,10mM/15V. At first disk-like conducting polymer which corresponds to nucleus was prepared and then monomer was added. Then many small dendrites grew. Figure 3 shows various kind of simulation of growth pattern. (a) is conventional DLA,.(b) is 3 directional DLA. It consists of the branches with the high density. When the particle attached, another 3 or 7 particles were added in Fig(c) or (d), respectively. These patterns appear well in actual conducting polymer.

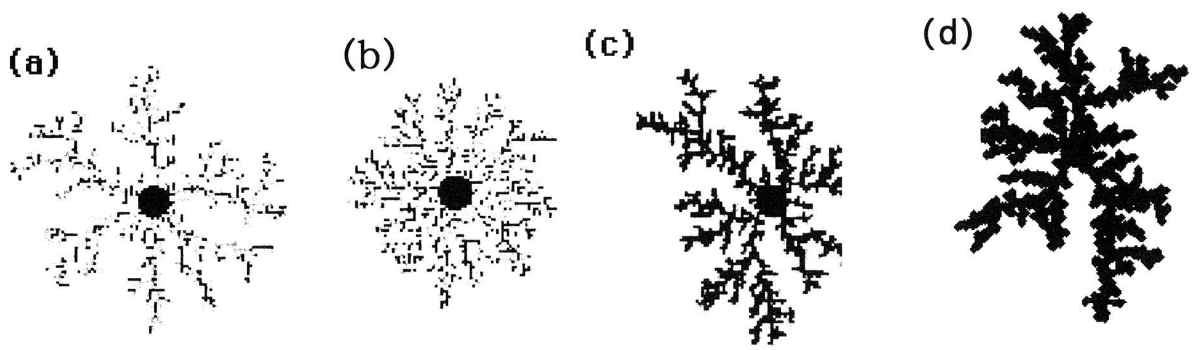

Fig.3 Various types of simulation patterns
(a) DLA model, (b) 3 directional walk model,
(c) 3 particles-added DLA when one particle meets growth pattern,
(c) 7 particles-added DLA

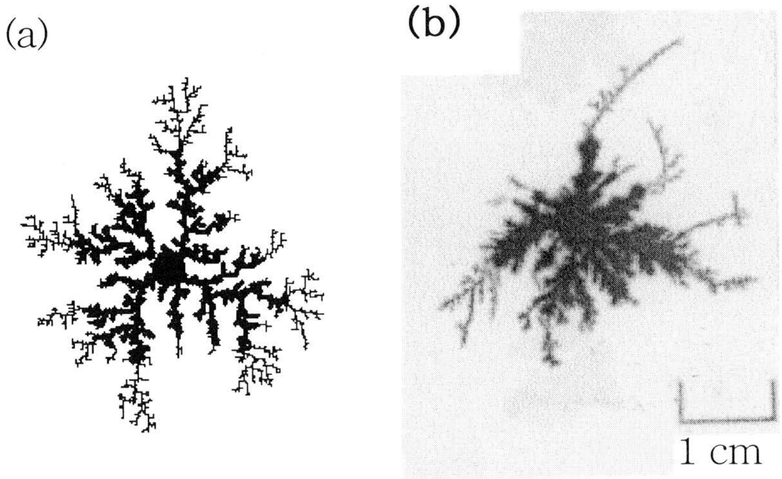

Fig. 4 Mode Change of growth mechanism
(a) Simulation, (b) Pattern after adding the monomer

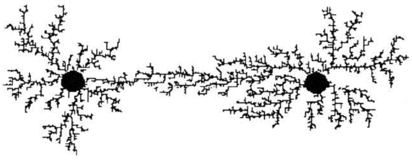

Fig 5. Connected simulation pattern of two neuron-type coducting polymer

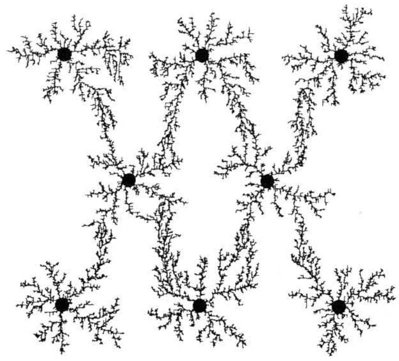

Fig 6 8-site network of neuron-type conducting polymer

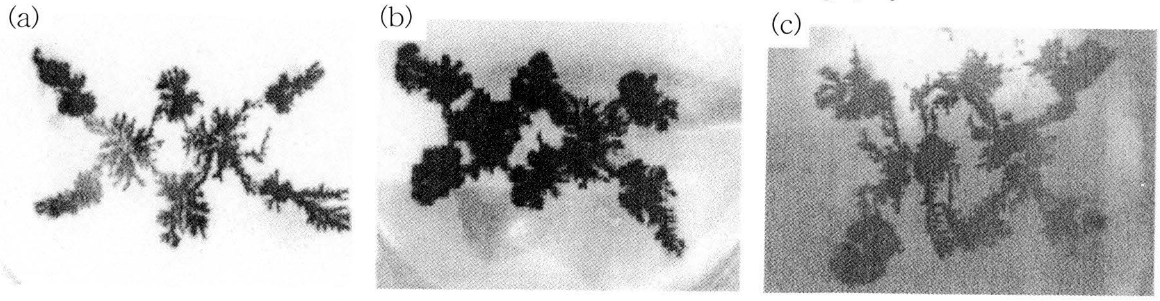

Fig.7 Acutal network of neurontype conducting polymer
(a)0.05M/0.1M/20V, (b)0.07M/0.05M/20V, (c)0.05M/0.1M/15V
/monomer/electrotyte/applied voltage/

Figure 4 shows the mode change of growth mechanism of conducting polymer. On simulation, same pattern as (c) in Fig 3 is simulated and then normal DLA model is applied(a) and Fig. (b) shows actual pattern when the monomer was added during polymerization. The branch width narrowed.

Connected neuron-type conducting polymer is also simulated as shown in Fig 5. This technique can be applied to network of conducting polymer. Figure 6 shows the eight-site neuron-type conducting polymer is simulated. Neural network system has three layer: input , intermediate and output layer. In this case, upper three sites are input terminals and lower tree sites are output terminals. Same type of network neuron-type conducting polymer were prepared using polypyrrole as shown in Fig. 7. The shapes of channel are different. This width also works as weight of the path in the network. More complicated simulation is required.

5. Conclusion

Network of neuron-type conducting polymer was prepared. Simulation program of growth pattern was developed.

Reference

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